TECHNICAL REPORT 1

MORPHOMETRIC COMPARISON OF HAYDEN PRAIRIE AND ADJACENT CULTIVATED AREA

by

Keith W. Anderson, Graduate Assistant

R. A. Lohnes, Assistant Professor of Civil Engineering

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IOWA STATE UNIVERSITY, AMES, IOWA

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ABSTRACT

Morphometric study of a virgin prairie area and adjacent cultivated farm land reveals no statistical difference in the slopes of the two areas. However, analysis by use of an elevation-percent area curve provides evidence that the landscape has been lowered about 0.132 feet in the last 100 years. Calculations of erosion rates using this curve are of the same order of magnitude as erosion rates calculated from sediment yield data. The erosion rates of individual basins are inversely proportional to the stream gradients in the basins. This observation is in accord with the equilibrium theory of drainage basin development and suggests that the erosion resistance of the glacial till varies between first order basins.

INTRODUCTION

Several virgin prairie areas of Iowa have been set aside as reminders of the landscape seen by the first white settlers, and have never felt the cutting edge of a plow. These prairies serve as wildlife refuges under the maintenance of the Iowa Conservation Commission.

We postulated that active channel erosion had virtually come to a halt on the virgin prairie since the thick vegetative mat impedes gulley development. The adjacent cultivated lands, on the other hand, have had the soil exposed to erosion since they have been opened to farming. A morphometric study of the landscape was made to give a quantitative estimate of man's effect upon erosional processes and provide a reference point in time for the evaluation of erosion rates.

Hayden Prairie, comprising 164 acres, located in north-central Howard County was selected as an example of virgin prairie. The prairie occupies the eastern half of Sec. 33, T100N, R13W. The area used as an example of cultivated land is north of the prairie and comprises the eastern half of Sec. 27 and the western half of Sec. 28 in the same township. This cultivated area was chosen because it is drained by the same tributary of Beaver Creek which drains the prairie.

The entire study area is part of one integrated drainage net developed on glacial till and is small enough that one may assume homogeneous climate throughout.

AGRICULTURAL HISTORY OF HAYDEN PRAIRIE AREA

According to the Soil Survey Report of Howard County (Orrben and Gray, 1925) the first white settlers entered Howard County in 1851. In 1855 the county was organized and a year later the first land entry was made. The wooded sections were settled first, mainly because of a need for building materials and because of their nearness to water and game. The first prairie settlements occurred in the 1870's (Berry, 1927). Although the study area is prairie, its nearness to Beaver Creek suggests that settlement may have occurred before 1870. An estimate of 100 years since first cultivation therefore seems reasonable.

PHYSIOGRAPHY AND CLIMATE

Gently rolling topography with a maximum relief of 66 feet characterizes the study area. Slopes range from 1% to 7%.

The virgin prairie portion contains a very shallow second order drainage system composed of three first-order basins. The cultivated land, in contrast, has a clearly defined second order drainage network with channels incised to a depth of two feet. The temperature and rainfall vary considerably throughout the year with peak precipitation of 20.78 inches in spring and early summer and peak temperatures of 97°F in July and August (Dept. of Commerce, 1964a). The mean annual rainfall is 33.6 inches and the mean annual temperature is 44.7°F (Dept. of Commerce, 1964b).

MEASUREMENT AND METHODS OF STUDY

Due to the small size of the study area and the absence of large scale maps, a plane table and alidade topographic map was made of the area. A two-foot contour interval and scale of 1 inch to 200 feet gave good control on the relatively flat terrain. In compiling the map, care was taken to place rod stations at divide crests and in drainage channels to achieve as high degree of accuracy as possible in the location of these critical points.

First order basins were defined according to Strahler's (1957) definition. The landscape in both portions of the study area was described by measuring stream length, basin area, maximum basin relief, and stream gradient as defined by Horton (1945). Slope angles were obtained according to the method proposed by Strahler (1950) in which only maximum valley wall slopes were measured. Slope measurements at drainage heads and down axes of spurs were not used.

Map length measurements were made with a Hamilton chartometer, and areas were measured with an electric grid-type counter. Stream length measurements presented no problem on the cultivated area; however, the low relief of the virgin prairie made definition and placement of streams difficult. The streams on the prairie were defined by rod stations located in the lowest part of the valley and verified by noting the shape of the contours and tone on air photos.

Hypsometric curves (Strahler, 1952) and percent area versus percent maximum relief curves (Schumm, 1956) and area-elevation curves (Lohnes, 1964) were constructed. An elevation-percent basin area curve was also

compiled in an attempt to more clearly evaluate the differences between the basins. This curve was constructed for each first order basin by plotting contour elevation on the ordinate, versus the area between the contour line and basin divide expressed as a percent of total basin area. This permits comparison of forms of basins of different sizes and elevations. By integrating the area between the mean prairie curve and each of the cultivated basin curves and then multiplying this number by basin area, it is possible to calculate the volume of soil eroded from the mean prairie surface.

Since there were only three samples in the Prairie for all measurements except maximum slope, no analysis of variance was attempted between the means of the two areas. However, there was a sufficient number of valley slope measurements for an analysis of variance of their means (Ostle, 1963).

PRESENTATION OF DATA

The means ($\bar{X}$), standard deviations (σ), and sample sizes (n) for the erosion rates, gradients, basin areas, stream lengths, maximum relief, and side slopes for the area adjacent to the prairie are shown in Table 1.

Table 1. Morphometric parameters of first order basins on cultivated land adjacent to Hayden Prairie.

	Erosion rate x 10^5 (ft^3/100 yr.)	Gradient x 10^{-2} (%)	Basin area x 10^4 (ft^2)	Stream length (ft.)	Maximum relief (ft.)	Maximum slope (%)
$\bar{X}$	1.14	2.75	89.9	969	45.0	4.5
σ	0.87	0.79	47.4	490	12.3	4.1
n	10	10	10	10	10	30

Similar data for the Hayden Prairie are shown in Table 2.

Table 2. Morphometric parameters of first order basins on Hayden Prairie

	Gradient x 10^2 (%)	Basin area x 10^4 (ft.)^2	Stream length (ft.)	Maximum relief (ft.)	Maximum slope (%)
$\bar{X}$	1.73	82.3	953.3	25.3	3.7
σ	0.55	35.7	284.5	5.02	1.6
n	3	3	3	3	30

Although the mean side slope angle on the cultivated portion of the study area is 4.5% and that on the prairie was 3.7%, an analysis of variance test indicated that this difference is not statistically significant. The distribution of the two samples is shown in the histograms of Fig. 1.

Hypsometric curves were plotted. However, since all basins were

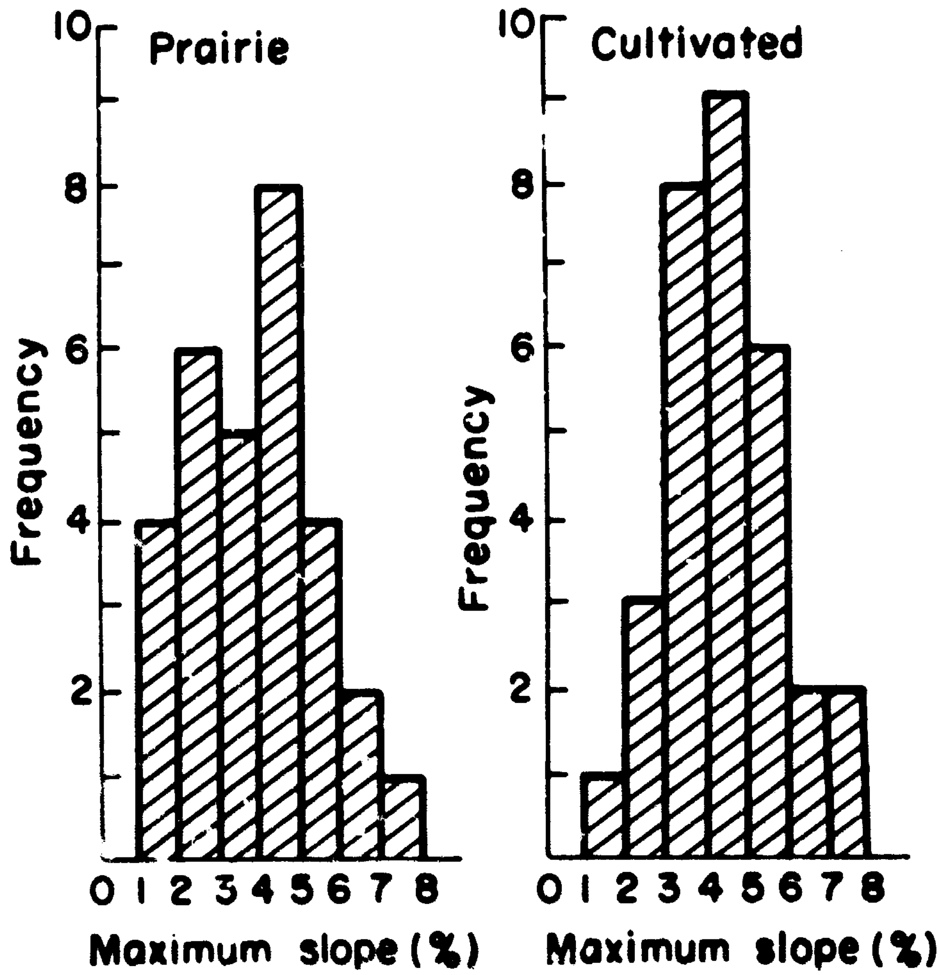

Fig. 1. histograms of valley side slopes for Hayden Prairie and adjacent cultivated land.

reduced to percentages on both ordinate and obscissa, no obvious differences were apparent according to the criteria for stage of erosional development established by Strahler (1952). The inadequacy of the hypsometric curves led to the development and use of elevation-percent area curves.

The elevation-percent area curves shown in Fig. 2 demonstrate the higher elevations of the three of first order basins on the prairie compared to those on the cultivated land. This is thought to indicate the amount of erosion or actual lowering of the landscape since the advent of farming to this area. By using these curves a mean volume of sediment loss from each first order basin was calculated to be 1.14×10^{-5} cubic feet. Since the time of initiation of this erosion can be estimated, it is possible to consider this as an erosion rate per 100 years.

Erosion rates were calculated by dividing the volume eroded by the basin area to give a mean value of 0.132 feet of landscape lowering per 100 years. In order to test the validity of this computation, the erosion rate was calculated for Pine Creek in north-central Iowa (Corps of Engineers, 1957) using a mean annual sediment yield of 1.1 acre-foot per square mile. The sediment yield data gives an erosion rate of 0.173 feet per 100 years. The similarity in order of magnitude of these results suggests that the elevation-percent area curve approach is a reasonable measure of erosion rate.

Since erosion rate depends upon the infiltration capacity and erosion resistance of the soil for a given climate and since the geometry of stream basins are thought to reflect the erodibility of

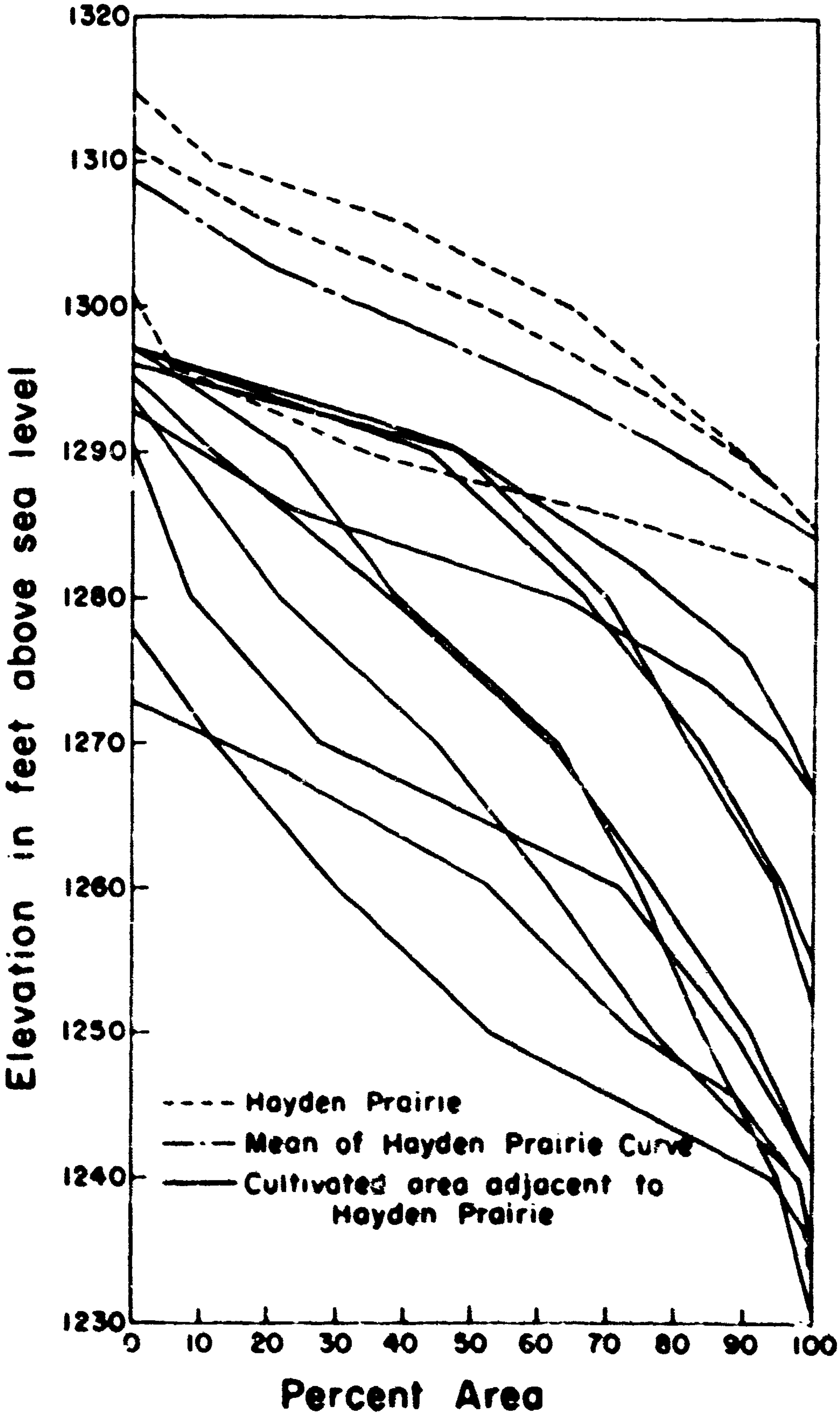

Fig. 2. Area-percent elevation curves of Hayden Prairie and adjacent cultivated land.

the soil, an attempt was made to correlate erosion rate with total relief, stream length, maximum side slope angle, and channel gradient. The only parameter which demonstrated a correlation with erosion rate is channel gradient and the graph is shown in Fig. 3. A least squares fit gives a correlation coefficient of -0.894 and the following equation for the relationship between erosion rate (E) and channel gradient (G).

$$G = -0.82 \times 10^{-7} E \times 3.69 \times 10^{-2}$$

This relationship supports the conclusion that channel slope is a dependent variable and will be steeper in areas of erosion-resistant rocks and lower in less resistant rocks (Mackin, 1948; Strahler, 1950; and Hack, 1960). Steep gradient streams flowing over areas underlain by quartzite contrasted with low gradient streams draining shale localities is an example used by Hack (1960) to illustrate that the geometry of the landscape is the result of equilibrium between gradational agents and the rocks upon which they act.

In other words, channel gradient is proportional to erosion resistance of the soil or rock over which the stream flows. Since erosion resistance is inversely proportional to erosion rate, it follows that higher erosion rates result in more gentle channel slopes. Although the entire study area is underlain by glacial till, these observations suggest that within this limited area there is a great deal of variance in the erodibility of the till. The equilibrium concept of channel geometry formation provides a rationale for the relationship shown in Fig. 3.

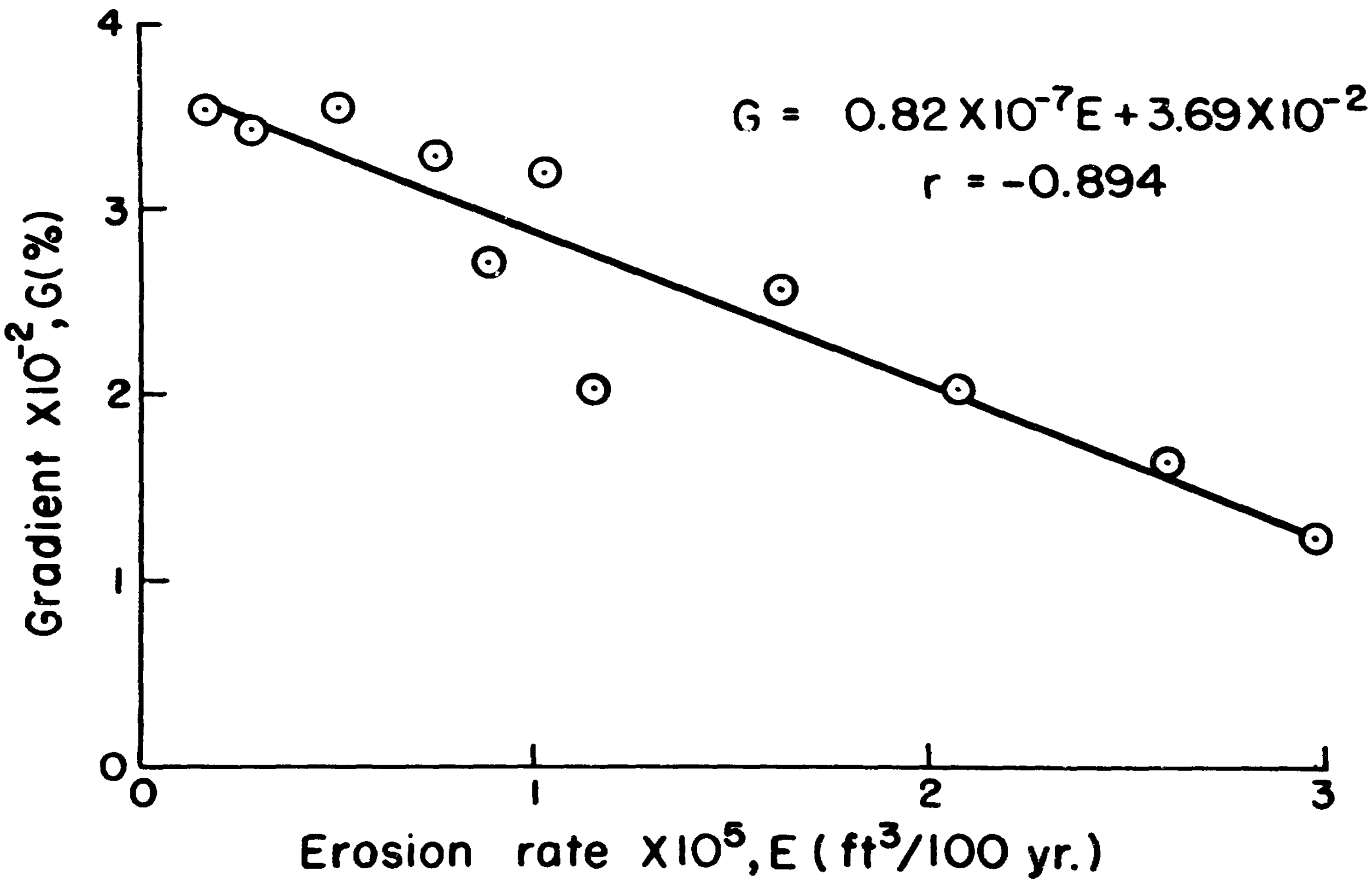

Fig. 3. Relationship between erosion rate and stream gradient.

CONCLUSIONS

The comparison of the quantitative aspects of the landscape of the Hayden Prairie and the adjacent cultivated land has led to the following conclusions:

1) Although the mean value of the valley side-slope angles in the cultivated area is higher than in the virgin prairie, analysis of variance lead to the acceptance of the hypothesis of equal means.

2) The elevation-percent area curves show that since this locality has come under cultivation the landscape has been lowered about 0.132 feet.

3) The erosion rates obtained from the elevation-percent area curves are of the same order of magnitude as erosion rates calculated from sediment yield data which seems to support the validity of the elevation-percent area curve approach.

4) Stream gradient is inversely proportional to erosion rate. This observation is in accord with the equilibrium concept of stream channel geometry and suggests that the erodibility of till differs from one first order basin to the next.

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